KNOW YOUR PRODUCT, BEFORE MARKETING COMPOST TO AGRICULTURE

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ABSTRACT

Composts vary from municipal solid waste treated with worms for less than one month, to windrowed feedlot manure maintained at above 50 degrees C for more than four months. The markets for compost include mulches, potting media, topsoil blends, and fertilisers. However, in a 1995 survey of 80 non-standard potting mixes, 70% did not support good plant growth. Products accredited to AS 3743 for Potting Mixes provide customers with an informed choice, but AS 4554 for Composts, Soil Conditioners and Mulches does not include **performance criteria** for specific agricultural applications. At the worst, the use of generic composts in agriculture has resulted in seedling emergence failure and yield reductions of over 30% and 25% respectively in cotton crops, the local elimination of earthworms in a vineyard, and severe leaf yellowing in oranges (Buckerfield and Webster 2001).

Knowing the agronomic properties of a compost is the best strategy for targeting markets in the agricultural sector. Standard laboratory tests for measuring the cation exchange capacity, total and available N, P and K, and electrical conductivity of soil (Rayment and Higginson1992) can assist producers to objectively match their composted product with a market. However, an indication of the biological maturity of the compost is essential to realize its full market potential.

INTRODUCTION

Claims for the agricultural benefits of compost include *instant results, even crop development, reduced salt problems, builds soil structure and healthy strong plants, reduces flower abortions, minimizes nutrient losses, increases water holding capacity, makes trace elements more available, less root diseases, enhances aroma and flavour, increases seed germination, increases crop yields, reduces sediment movement, increases nitrogen fixation, stabilizes soil temperature, increases production of root/leaf exudates, stimulates secondary metabolites, and source of humic/fulvic acids* (Wilson 2002). A wonderful wish list, but for which compost, applied at what application rate, for what purpose, to which crop, in which soil type, managed under what conditions? What if we add *reduced germination of cotton by over 30% in two successive seasons*, *cotton yields up to 25% lower*, *the complete elimination of earthworms in a vineyard,* and *extreme leaf yellowing of oranges* (Buckerfield and Webster 2001) to the claims quoted above?

Would a producer suffering these negative results ever consider purchasing compost again?

Too many composts are sold under the 'muck and mystery' banner, when a little objective thought and testing can improve both the confidence of the consumer applying the product, and the marketing focus of the compost producer. In this paper I will outline what can go wrong and why, and justify the need for more objective **performance criteria** to be established for products targeting the agricultural sector.

POTENTIAL MARKETS AND PERFORMANCE CRITERIA

The varied starting materials used in the composting process and the biological maturity of the compost at the point of application both have a huge impact on the **agronomic properties** of the product (refer to Table 1). Raw materials such as animal manures have very high nitrogen (N), phosphorus (P) and potassium (K) concentrations (macronutrients required by plants), and would best be marketed as fertilisers. **Performance criteria** for products used as a fertiliser includes knowing the concentration of plant-available nutrients in the compost, to enable producers to replace conventional fertiliser inputs. Costs of production may then be reduced, even without the benefits of organic carbon inputs being factored into the analysis. The Australian Standard for Composts, soil conditioners and mulches (AS 4454, 2003) uses particle size ($\leq$16 mm) and physical contaminants as **performance criteria** for soil conditioner composts, but no reference is made to specifying the total and available N, P or K concentrations on a dry weight basis (used for calculating fertiliser equivalence), and nitrogen drawdown testing is not required. Yet, the reported *reduced* (cotton) *germination by over 30% in two successive seasons* and *cotton yields up to 25% lower* (Buckerfield and Webster 2001) are likely to have occurred when compost was applied as a soil conditioner prior to sowing the crop.

Material (fresh)	**C:N ratio**	**% N (dry wt)**	**% P (dry t)**	**% K (dry wt)**	**% lignin (dry wt)**	**Bulk density (kg/m^3)**	**% water (dry wt)**
Pig manure	7-24	1.9-5.6	0.4-1.2	0.1-4.8	2.2	272	65-91
poultry m'ure	2-24	1.6-10	1.1-2.3	1.7-2.2	3.4	263-563	22-75
Abattoir waste	14-17	8-11	3.0-3.5	2.0-2.5		507	80-85
Green waste	**13-17**	**0.6-0.8**	**0.3-0.4**	**0.5-0.6**			
Peanut shells		0.8	0.15	0.5	23		
Corn stalks	60-73	0.8		0.8	11	11	12
Wheat straw	100-150	0.3-0.5	0.15-.26	0.6-1.02	7-18	20-131	4-12
Sawdust	200-511	0.1	0.01-0.5	0.04-1.4	15-28	122-156	19-65

Table 1: Comparison of the chemical and physical properties of agricultural organic wastes used for composting. Physical and chemical data are compiled from numerous sources.

Materials to the bottom of **Table 1** (those with low NPK concentrations), can be used as bulking agents and as a source of organic carbon to improve the composting process of the nutrient richer, more dense materials at the top of the table (Pittaway 2002). They also have some highly desirable features of a mulch, provided that the particle size is of the order of 20 mm. Very high carbon (C) to N, C to P and C to K ratios slows microbial degradation (greater persistence), as does the higher concentration of lignin typically contained within these plant residues. Mulches are usually applied at a much higher rate than fertilisers or soil conditioners, so persistence is a key **performance criterion**. Mulches suppress weeds, reduce the evaporative loss of water from the soil (Pickering et *al*. 1998), buffer the soil from temperature extremes, and are a habitat for soil animals responsible for improving the pore structure of soil (Wardle et *al*. 2001). AS 4454 (2003) uses particle size ($\geq$16 mm) and physical contaminants as criteria, but reference is made only to upper application limits for phosphorus-sensitive plants (4L/m^2). No requirement for self-heating, toxicity, nitrogen drawdown, or moisture content is considered necessary, for composted or pasteurized mulches. Yet, the *extreme leaf yellowing* problem in an orange orchard, and the *complete elimination of earthworms* under the vines in the vineyard (Buckerfield and Webster 2001) most likely resulted from the application of compost or mulch.

UNDERSTANDING THE COMPOSTING PROCESS TO MARKET YOUR PRODUCT

The aim of composting is to fuel the activity of microorganisms by providing a source of organic carbon, oxygen, water and inorganic nutrients, to break down complex compounds into minerals and simpler, more readily degraded compounds (slow-release nutrient reserves). Heat and humus-like compounds are produced as microbial bypoducts, and carbon dioxide is lost to the system as a gas. The nutrient concentration of the compost increases, as a consequence of transforming organic carbon into carbon dioxide, which is lost to the air as a gas (refer to the bars in **Figure 1**). However, the **plant-availability** of the key nutrients N and P changes over the composting cycle (refer to the change in the clear and solid sections of the bars in **Figure 1**). The combination of warm, wet, well aired and well fed stimulates

microbial growth to such an extent, that any readily available nutrients will be locked up within the microbial cells (referred to as nutrient drawdown, the solid bars in **Figure 1**).
In both AS 4419 (2003) and AS 3743 (2003) the nitrogen drawdown index is a required test. However for AS 4453 (2003) the drawdown index is not required for mulches, nor for products labelled as manure. Yet the plant-availability of key nutrients and the likelihood of nutrient drawdown occurring after application are critical **performance criteria** for the use of a compost both as a mulch and as a fertiliser.

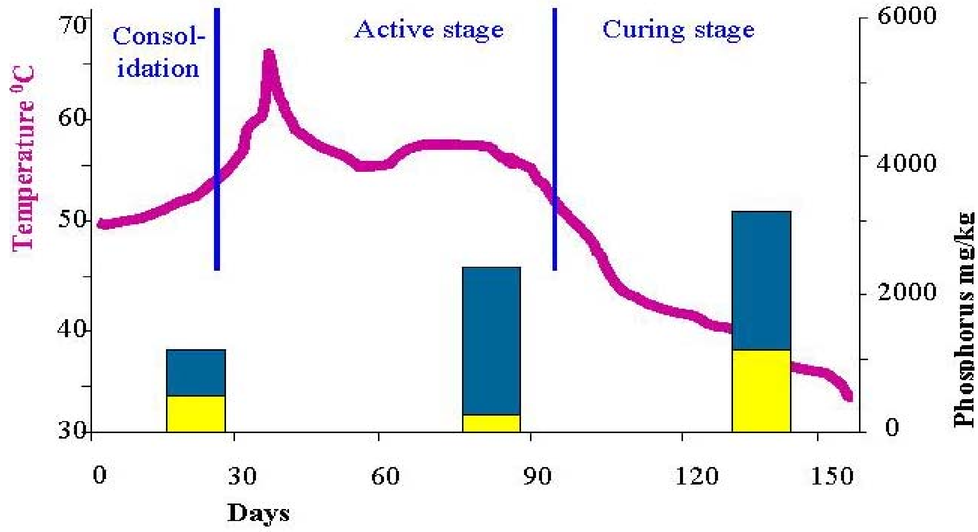

Figure 1: The three stages of composting. The bars are the concentration of phosphorus, divided into plant-available inorganic P (clear portion) and unavailable organic P (solid portion). The solid line is the core temperature within the cotton trash windrow

If a compost sufficient in organic carbon but deficient in other nutrients is added to a soil, microbial activity will be stimulated, drawing available nutrients from the soil (Patriquin 1986). This phenomenon of 'drawdown' is not unique to nitrogen. Plants can be starved of the other major nutrients, due to the competitive advantage of microbes for nutrient uptake. For this reason, microbially active (immature) composts should not be used for potting mixes or as fertilisers for actively growing plants (Hoitink and Poole 1980). Instead, composts should be processed into the curing phase, where the exhaustion of available organic carbon supplies cools microbial activity (reduced temperature in **Figure 1**), and where nutrients such as phosphorus, nitrogen and calcium become more plant-available. For composts based on poultry manure, this may occur after 16 weeks of composting, but for cotton trash the nutrient drawdown phase may last for 20 weeks (**Figure 2**). This is due to the difficulty in initially wetting up the compost, extending the duration of the consolidation phase.

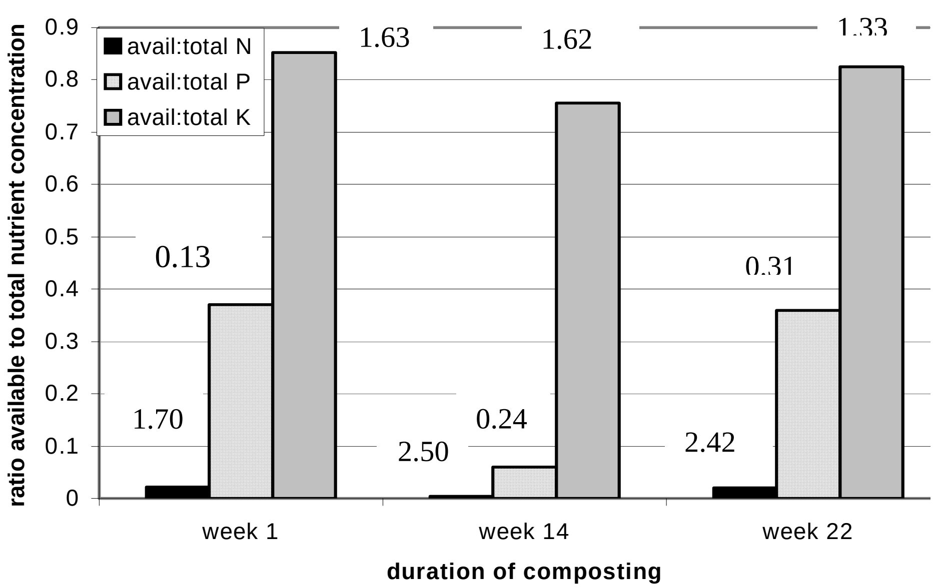

Figure 2: Plant-availability of N, P and K in a cotton trash compost over the duration of composting. The values above the bars are total concentration of the nutrient as a percentage of the dry weight of the compost, based on soil testing methods (Rayment & Higginson 1992), not AS 4454.

If the cotton trash compost was applied to an orange orchard before about week 18 at a relatively high application rate, both N and P drawdown would have occurred. This would explain the *extreme leaf yellowing* recorded by Buckerfield and Webster (2001). **Figure 2** also highlights how misleading a statement about the total nutrient concentration of the compost can be. Whilst the total nitrogen concentration is a respectable 2.5% at week 14, the N drawdown index would be unacceptably low, and the immaturity of the compost would lead to N starvation if applied to growing plants or seedlings. **Figure 3** shows the consequences of immature compost drawing down nitrogen in a broccoli crop. The application rate was calculated on the basis of the total N concentration of the compost, with 11 t/ha applied to match the needs of the crop. As the numeral values for the nitrate levels measured in the sap of the broccoli prove (only strawberry clover and bare soil treatments tested), compost treated plants were starved of N, rendering them much more attractive to aphid attack!

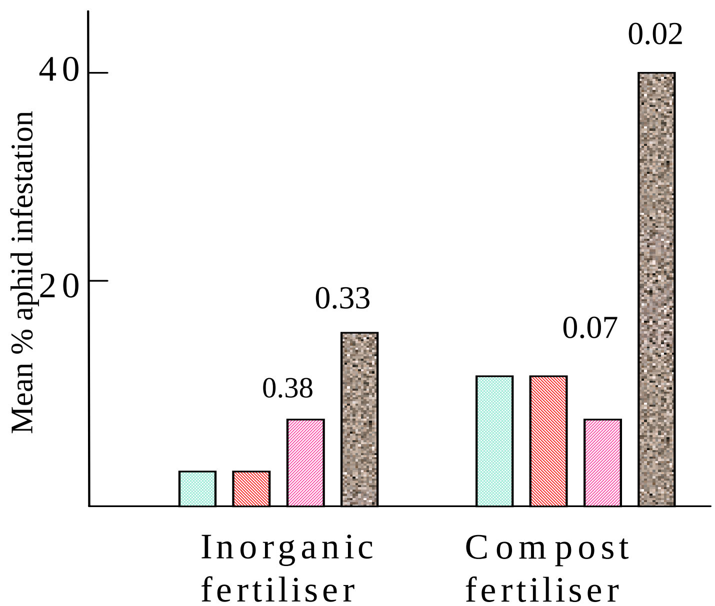

Figure 3: Effect of living mulches (white clover = diamonds, red clover = backslash, strawberry clover = forward slash) on aphid infestation on broccoli. Bare ground controls = stippled bars. Inorganic treatments were fertilised to meet the needs of the crop for N, P and K (left hand series of bars), the other had immature compost applied at 11 t/ha. Numerals are % nitrate levels in the broccoli sap. The nitrogen-stressed compost-treated plants had head weights 35% less than the inorganic treatment and attracted higher aphid numbers, particularly in the absence of living mulches. Data modified from Costello (1994)

Tree crops such as oranges are at high risk from immature composts, as they are surface feeders. Note the very high concentration of K in **Figure 2**, which in contrast to N and P remains highly available to plants over the duration of composting. The concentration of K is 1.6% on a dry weight basis, of which about 80% remains available for plant uptake (inorganic). K is a component of the cell water, whereas N and P are locked up in the structure of the cell. At the time of application, 80% of the total K is available as a fertiliser, but less than 10% of the total N and at the most 35% of the total P is available.

Farmers must have this information to enable them to calculate an appropriate application rate of compost and fertiliser to meet the needs of the crop for N,P & K over the first growing season. Follow-up soil testing will quantify the release of compost N and P over subsequent seasons.

In the past, farmers have been encouraged to use composts on the basis of their total N level. If a farmer did this with the cotton trash compost in **Figure 2**, the plants not only would be starved of soil N as was the case in the broccoli crop in **Figure 3**, but could suffer an excess of K and possibly P. Indeed, inappropriately high applications of K in the compost applied to the cotton crop could explain the seedling emergence failure over two successive seasons and the reduction in final yield recorded by Buckerfield and Webster (2001). K is a very water-soluble salt, with a high electrical conductivity (EC). If the compost was high in K (refer to K concentrations listed in **Table 1**), application in excess of the crop requirements could have burnt the seedlings. AS 4454 refers to an upper application rate of 50 L/m^2, which equates to 75 t/ha dry weight of the cotton trash compost in **Figure 2** (1 t/ha K), and the lower rate of 4L/m^2 equates to 6 t/ha (80 kg/ha K). In **Figure 4**, an example of the unintended salt burning effect of over-application of manure is illustrated for a cabbage pot trial. This is not a composted product, but even if composted, the K concentrations and therefore the EC would still be very high.

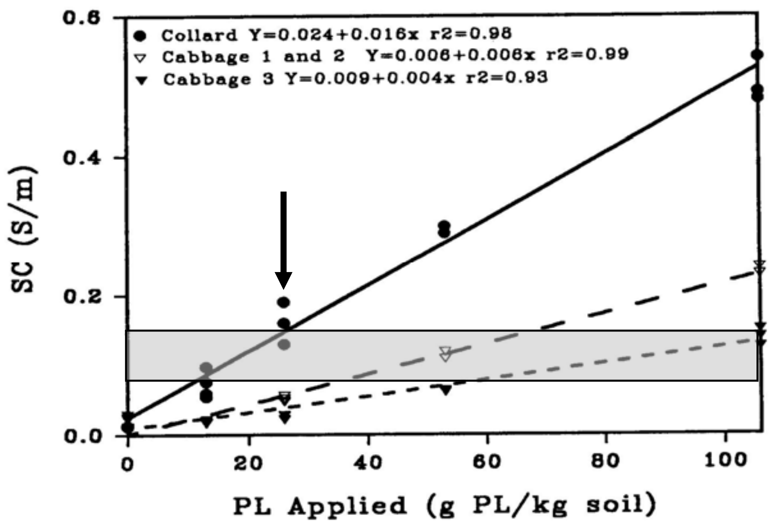

Figure 4:
Effect of different rates of application of uncomposted poultry litter on the specific conductance of soil used to grow three consecutive crops of cabbages. The grey bar is the specific conductance range considered to induce 50% yield reduction in fruit and vegetable crops, sensitive forage and field crops in the Alabama region. The black arrow is equivalent to 26 ton/ha compost (dry wt), resulting in complete seedling emergence failure (Ningpin Lu and Edwards 1994)

In the cabbage experiment, seedling emergence was reduced in 3 successive crops (collards are small cabbages). In the uncomposted poultry manure, the K levels would have remained consistently high in the absence of leaching rains, whereas the initially high ammonia concentrations would have been microbially transformed about 2 to 3 weeks after application. Excessively high K levels in the mulch reported by Buckerfield and Webster (2001) could easily be responsible for repelling all earthworms from under the grape vines (burning effect due to very high EC). Alternatively, if the mulch was smaller than the 16 mm particle size specified in AS 4454 2003) with a low EC, and if it was still in the active composting phase when applied, the worms may have been repelled by elevated carbon dioxide levels. If the mulch had a high bulk density (refer to **Table 1**), a small particle size and stimulated high microbial activity after application, the lack of passive air exchange would have resulted in the microbes scavenging all available oxygen, elevating the carbon dioxide levels, at the expense of the worms!

Checking the nitrogen drawdown index or using the reheating test (AS 4454 2003), ensuring that the particle size was above 16 mm and checking that the rate of application (dry weight basis) of the mulch did not add excessive K to the soil would have avoided the problem.

THE CASE FOR COMPOSTING ALL ORGANIC MULCHES & SOIL CONDITIONERS.

In both AS 4419 (2003) and AS 3743 (2003) all potting mixes and landscape and garden soils must meet toxicity test thresholds. In AS 4454 (2003) if the compost is based on manure, or if the product is considered a mulch, no toxicity testing is required. This is a major problem given that mulches are typically produced from shredded or chipped plant material, particularly woody plants. The durability of woody plants (to a lesser extent even annuals), is due to the production of chemical toxins circulating within their tissues or stored in non-living bark and wood (Edwards and Wratten 1980). These toxins are produced explicitly to deter predators (eg bitter tasting, chilli hot), or to kill microbes and predators (eg cyanide compounds, alkaloids, terpenoids, 1080). Many of these chemicals are also toxic to unrelated plant species, and can inhibit the germination and growth of sensitive plants (allelopathy, Keeling et *al.* 1994). During the consolidation phase of composting, the action of specialized microbes capable of detoxifying and destroying these chemicals is required before the general microbial population can function. Detoxification may take 2 to 3 weeks, before the elevated temperatures characteristic of the active phase can be established.

Pasteurisation does not detoxify these chemicals, and may not be sufficient to kill weed seeds and some pathogens. Therefore, the minimum of 6 weeks composting in AS 4454 (2003) is recommended to detoxify mulch. Composting into the curing phase has the added advantage that the concentration of plant-available nutrients and humic-like substances will also increase. The lignins and phenolics contained within hardened tissue (refer to **Table 1**) react biochemically with the secretions of microbes over time to become complex organic molecules. True humus takes decades to develop within soils, but these humus-like substances produced during the curing stage of composting can have high nutrient and water holding capacities (Outamame et *al.* (2002). This humus-like property of a compost is best measured using a Cation Exchange Capacity (CEC) test (variable charge method, Rayment and Higginson 1992). The CEC of sandy soils is of the order of 10, that of fertile clays can be 40, but composts including sawdust as an ingredient can exceed 120 meq/100 gm of sample.

So, why sell *muck and magic* when composts and mulches can be objectively defined and tested, to identify the best market? *Buyer beware* is not the best way to dream up application rate recommendations, and will most certainly not encourage repeat business from customers. Cost-effective composts have a lot of merit for the agricultural sector, and compost producers have a lot to gain by understanding the agronomic properties and problems associated with their products.

The Australian Standards for Potting Mixes and for Soils for Landscaping and Garden Use provide both producers and customers with very comprehensive guidelines to ensure that the product is fit for purpose, AS 4454 for Composts, Soil Conditioners and Mulches does not. However, by using the tests recommended in this paper, composts and mulches can be used with confidence in agriculture, producing repeatable environmentally and economically beneficial results.

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